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A CONTINUOUS-LOOP CARTRIDGE RECORDER FOR U.S. NAVY APPLICATION.(U)
JUN 79 W G CLEMENT, R R WALLSTROM N66001-78-C-0117

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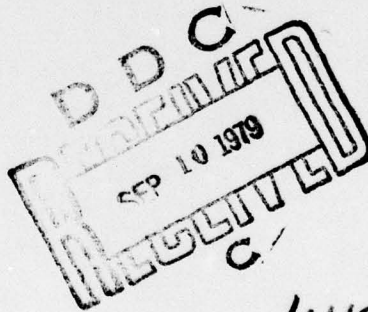
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Technical Document 261

A CONTINUOUS-LOOP CARTRIDGE RECORDER FOR A U.S. NAVY APPLICATION

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WG Clement
NOSC
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N66001-78-C-0017

411359

New

29 June 1979

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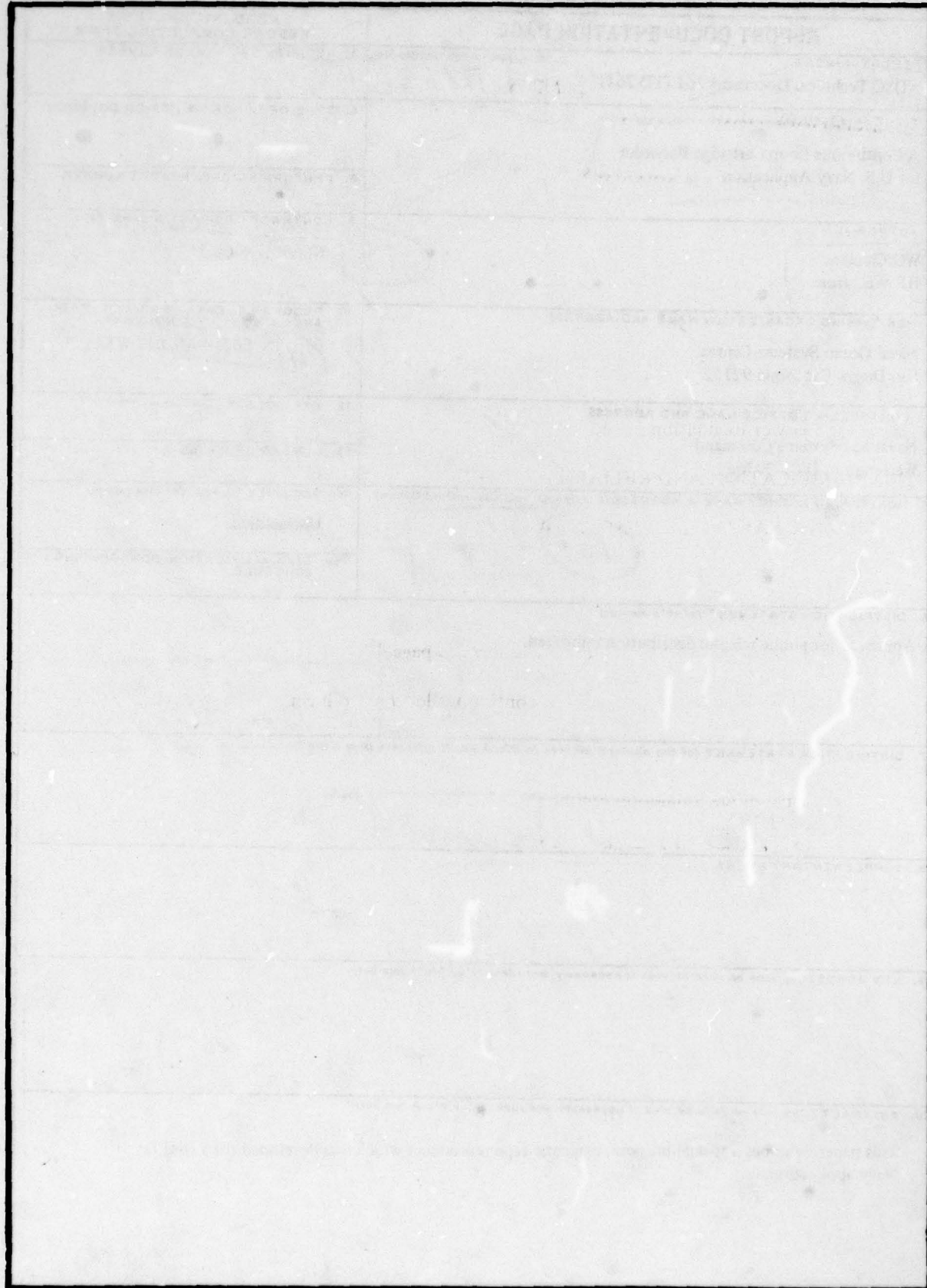
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INTRODUCTION

The purpose of this paper is to describe a special-purpose, magnetic-tape reproducer, the design of which has evolved through several embodiments over a period of approximately 10 years. The device is uniquely suitable for a specific Navy application. However, it is sufficiently versatile in its capability to appear well qualified for many other applications. It is hoped that the information contained herein will reach the attention of other engineers with similar requirements who may find it profitable not to have to "reinvent the wheel."

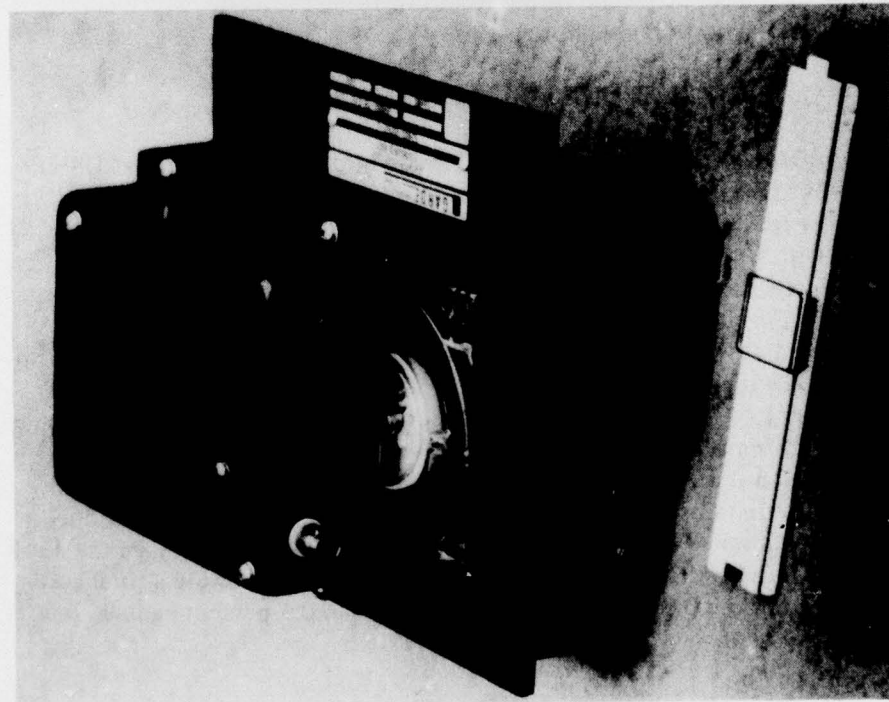
The Navy requirement was for a direct-mode, single-channel, reproduce-only device. The design is modular, however, and provides for the addition or deletion of either record or reproduce functions as well as a choice of the number of channels and the various modes of recording, such as direct, FM, or digital. A basic limitation is that only 1/4-in tape can be used. Other Navy requirements were small size, low weight and power consumption, simple and reliable tape replacement, flat response from 50 to 5000 Hz, minimal flutter especially at low flutter rates, long-term speed constancy, uniformity of performance from unit to unit, and high reliability with minimal maintenance.

An earlier model of the tape reproducer was produced in 1972 by the Audio Instruments Company in Mountain View, CA.¹ Subsequently, the same model was produced by L'Garde Products Corporation of Newport Beach, CA. L'Garde is currently producing a modified version of this same model for the Navy on a subcontract with Gould, Incorporated, Cleveland, Ohio. L'Garde recently completed a contract with the Naval Ocean Systems Center for the development of an improved version of the Audio Instruments model which is the subject of this report. Figures 1A and 1B are photographs of the device.

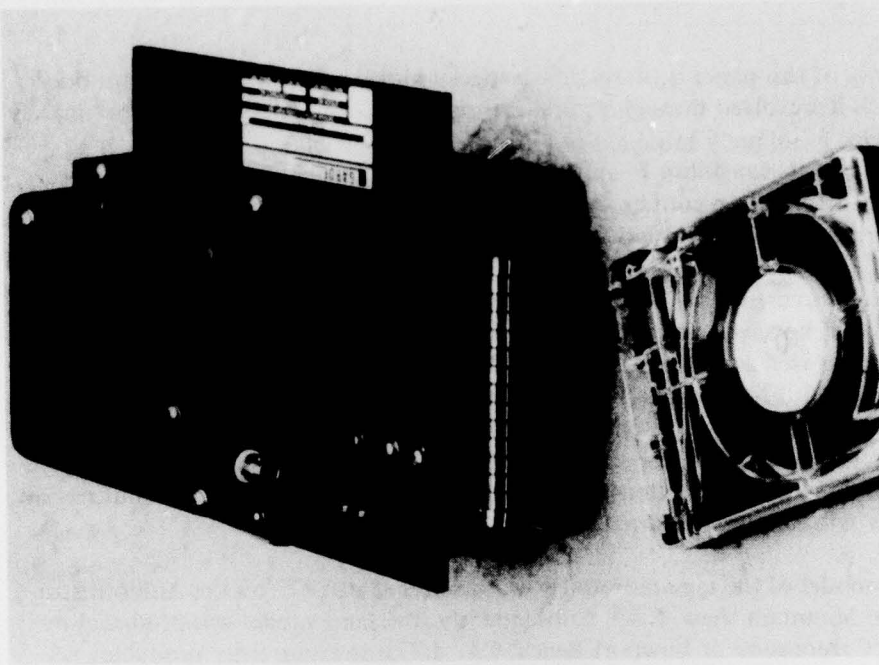
OPERATIONAL CAPABILITIES

The Tape Loop Reproducer reproduces a single track of data prerecorded on 1/4-in magnetic tape at 3.75 in/s (IPS). A second track containing a prerecorded 3814-Hz signal serves as a tape-speed reference for a multiloop digital phase-lock servo drive system which controls tape speed to within ± 0.05 percent. A digital tachometer affixed to the capstan drive motor shaft provides an alternate or back-up speed reference. If the prerecorded speed-control reference is of insufficient level or incorrect frequency the tachometer reference is automatically substituted. These conditions occur during start up and may also occur when tape drop-outs are experienced. A significant advantage of a prerecorded speed-control reference is realized when the frequency or frequencies of the data reproduced must be precisely the same as when recorded. An additional advantage is the automatic elimination of low-frequency flutter components, caused not only by tape-speed variations in the device being described, but also by all tape-speed variations which may have occurred during record and reproduce iterations from the time of original data acquisition. Flutter measurements made on the Tape Loop Reproducer with a MINCOM Model 8300A-W IRIG flutter meter indicate a total accumulative flutter over a band from 0.5 to 625 Hz of no greater than 0.5-percent peak 95 percent of the time.

¹ Naval Undersea Center, NUC TN 866, October 1972.



Part A



Part B

Figure 1. Continuous-loop cartridge reproducer.

The tape is totally contained within a standard NAB type A cartridge, and tape cartridges can be interchanged quickly and conveniently without the need for touching the tape. A total of 21 minutes of tape reproduce time at 3.75 IPS is available before the data repeats itself. Reference 2 describes the specific cartridge used. No pressure pads are used.

The reproduce amplifier provides standard NAB equalization and an output voltage of 5-V peak for a 1-kHz signal recorded on Ampex 675 lubricated tape at the 1-percent third-harmonic distortion level. A 12-step, 2-dB per step attenuator allows reduction of the output from this level to 0.4-V peak. Frequency response of the reproducer is flat from 50 to 5000 Hz within 2 dB referenced to the output at 500 Hz. The 1-percent third-harmonic distortion signal level plus noise output voltage is approximately 52 dB above the band-limited noise floor.

The Tape Loop Reproducer operates on 28 VDC and performs within specification over a range of input voltages from 22 to 34 VDC.

CONFIGURATION

The Tape Loop Reproducer occupies approximately 0.2 ft³. Figure 2 is an outline-dimension drawing. Signal output is provided by a BNC bulkhead-mounted connector. Input power of 28 VDC at less than 1.0 A is furnished through a MIL standard MS3114E14-19 type connector which is also bulkhead mounted. The Tape Loop Reproducer itself is mounted by flanges which may be drilled for a variety of hole patterns and fastened directly or via vibration isolators to the vehicle or testbed in which the device is to be used. Total weight, including the tape cartridge, is 5.5 lb.

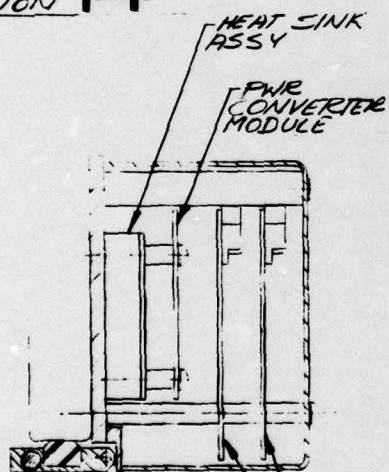
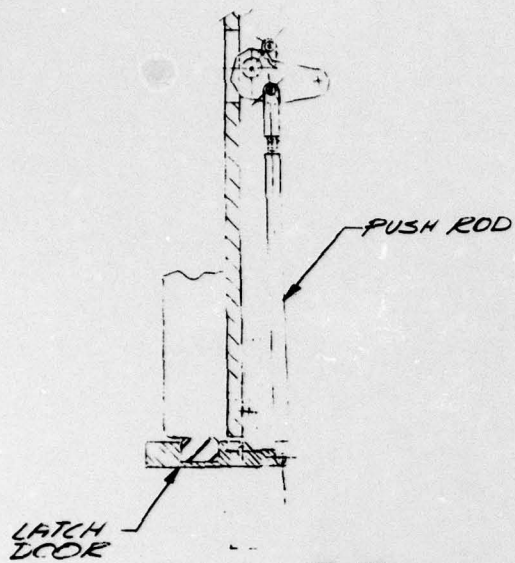
MECHANICAL DESIGN

The basic structure of the unit consists of a machined aluminum casting. All the major components, including the record and reproduce heads, are attached to this base casting, and the tape cartridge is spring-loaded against it, thus facilitating proper alignment with the record and reproduce heads.

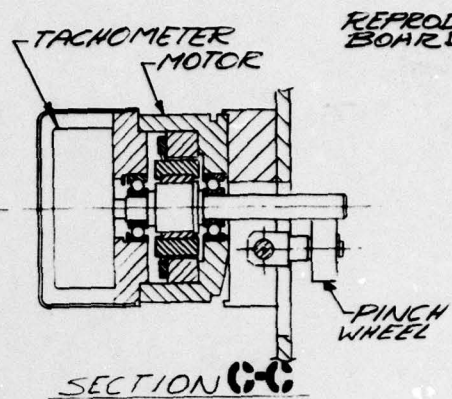
The drive motor is an Inland Model 0T1316A DC torque motor, the shaft of which serves directly as the tape-drive capstan. The tachometer rotor, consisting of a glass disc containing 1000 photo-etched lines, is mounted directly on the opposite end of the motor shaft. The capstan diameter is held to within 75 μ in of its nominal value with total accumulative run-out held to 100 μ in. The motor runs at 3.814 RPS for a tape speed of 3.75 IPS. Each motor is given a special assembly and run-in treatment to minimize speed variations due to cogging. Class 7 instrument grade ball bearings are used to support the motor shaft in its housing.

The pinch-roller consists of a neoprene rubber rim molded on a steel hub in the center of which is inserted a bronze bushing. The pinch-roller rotates on a chrome-plated stainless-steel shaft and is spring-loaded against the capstan by a solenoid-actuated linkage when the

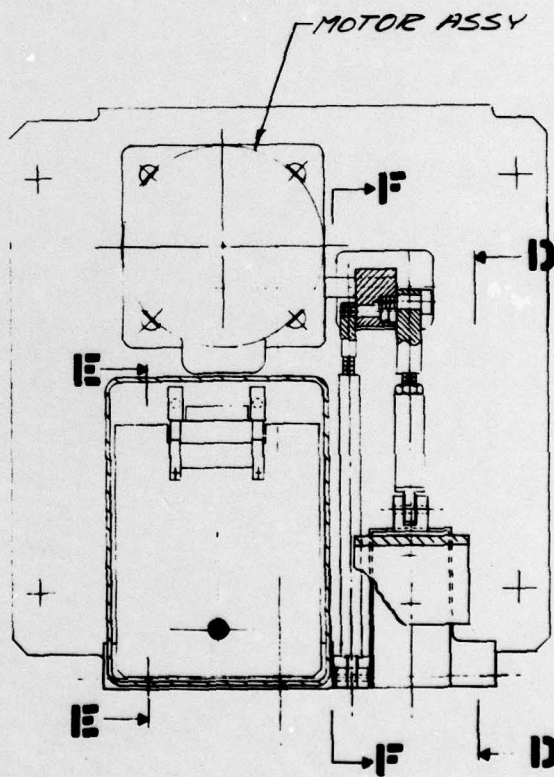
² "The status of Broadcast Cartridge Design," Manierre, Journal of the Audio Engineering Society, May 1973.



SERVO BOARDS NO. I & II



REPRODUCE BOARDS



BOTTOM VIEW

TENSIONER

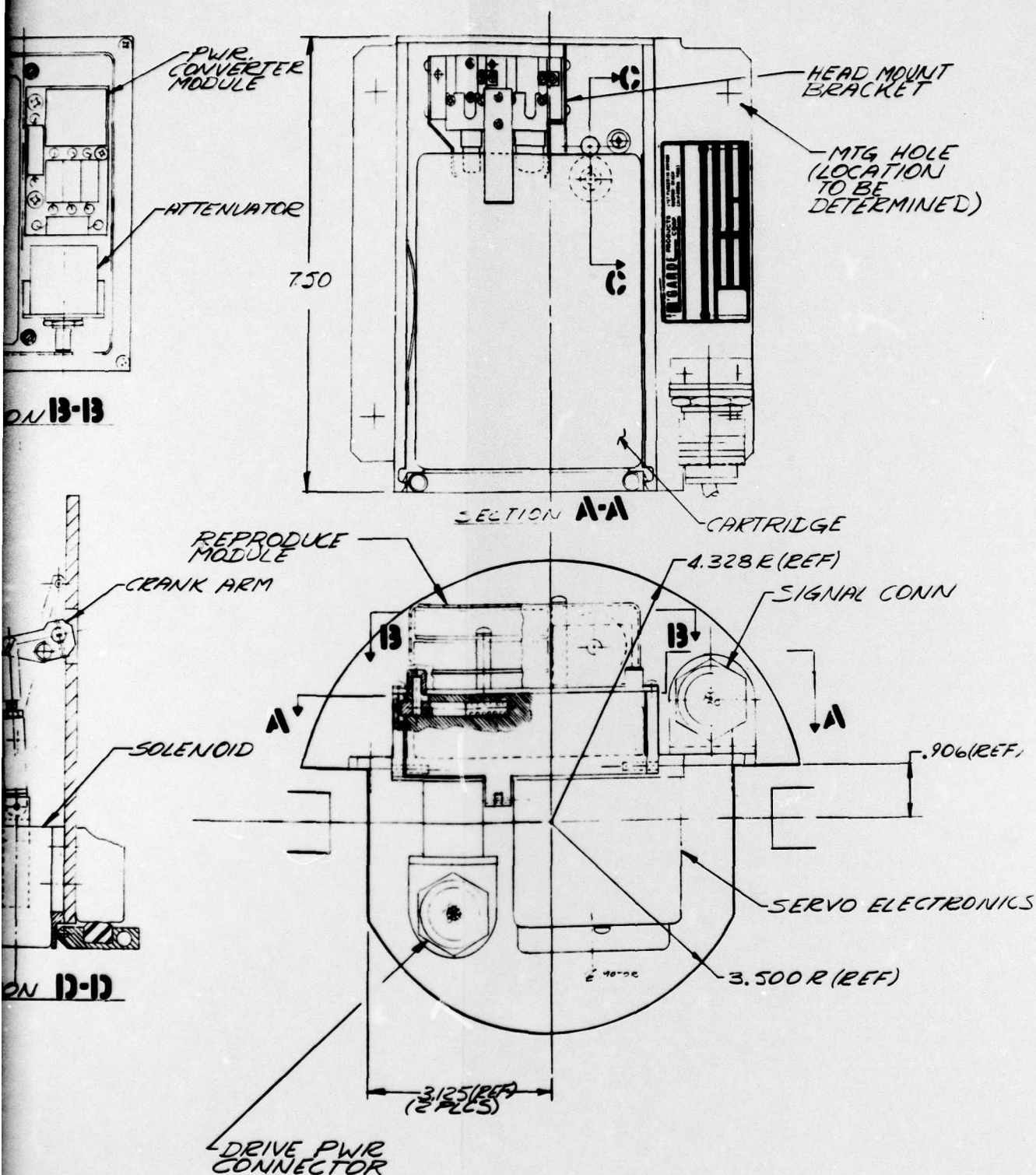


Figure 2. Outline-dimension drawing of continuous-loop reproducer.

tape reproducer is energized. When power is turned off the pinch-roller is forced away from the capstan so that compression set, which could result in tape flutter, is avoided. Each pinch-roller is ground to a precise diameter and concentricity to minimize its contribution to tape flutter. Special tooling is used during assembly of the reproducer to ensure the precise dimensional relationship required between capstan and pinch-roller.

The pinch-roller is inserted into the tape path by a mechanical linkage attached to the latching "tailgate" which holds the tape cartridge in place. When the tailgate is opened, preparatory to changing the tape cartridge, the pinch-roller is simultaneously lowered out of the tape path allowing the cartridge to be removed.

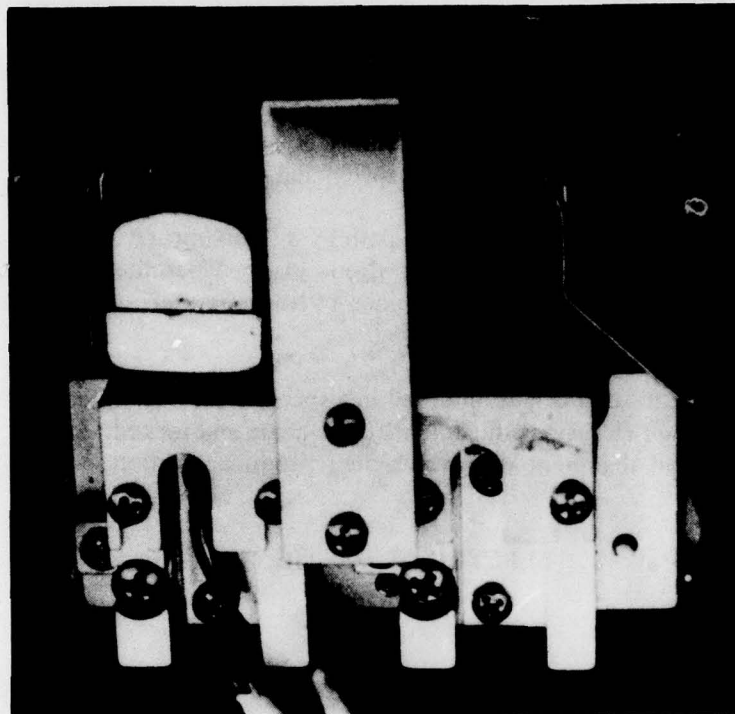
The reproduce head (figure 3) is mounted in a special assembly which permits the necessary azimuth, tilt, and elevation adjustments to be made and locked. Special jigs are used for approximate head alignment after which the reproduce function serves to establish a final alignment.

ELECTRICAL DESIGN

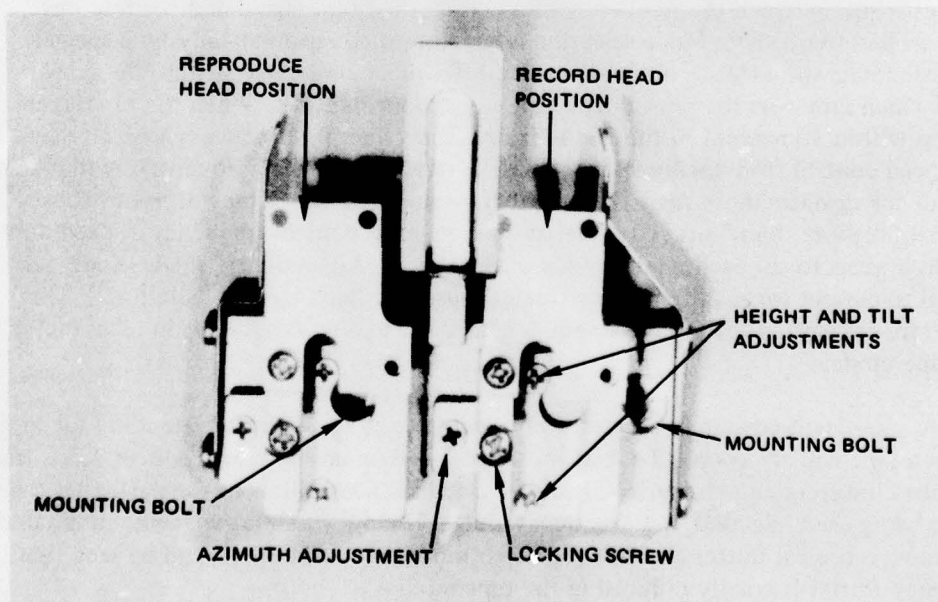
TAPE-DRIVE SYSTEM

Tape speed is controlled by a dual-mode, dual-loop, digital phase-lock servo circuit (figure 4). In the "tachometer" mode, motor speed is sensed and corrected for minimum error. The error signal is derived by comparing the frequency output of a digital tachometer mounted on the motor shaft with a reference crystal-controlled frequency. In the "tape" mode, tape speed is sensed and corrected for minimum error, the error signal being derived from a comparison between the frequency of a prerecorded tape signal and the reference crystal-controlled frequency. Mode selection is accomplished automatically by a special medium-scale-integration (MSI) integrated circuit frequency-selective switch, the sensor portion of which monitors the reproduced tape signal continuously. When the tape signal frequency is within 10 percent of the 3814-Hz nominal value, the frequency-selective switch transfers speed control from tachometer control to tape control. Subsequently, if the tape-signal frequency deviates more than 10 percent from nominal or if a tape drop-out causes loss of signal for more than 3 ms (10 cycles of the low-limit control frequency), speed control immediately reverts to the tachometer mode of operation. An auxiliary single-mode servo loop is used to correct for high-frequency flutter caused by head-to-tape "stiction." This auxiliary loop is always in tachometer mode whether the main servo loop is in tachometer mode or tape mode.

Two significant advantages accrue from operating the tape-drive system in tape mode. First, a given tape will always playback at the same speed on any tape reproducer. This translates into absolute frequency integrity of the recorded data regardless of the particular tape reproducer being used. Second, low-frequency flutter (below 10 Hz) is virtually eliminated. Figure 5 shows a typical flutter spectrum for each mode of operation. It can be seen that low-frequency flutter is greatly reduced in the tape mode.



Part A



Part B

Figure 3. Head-mounting assembly.

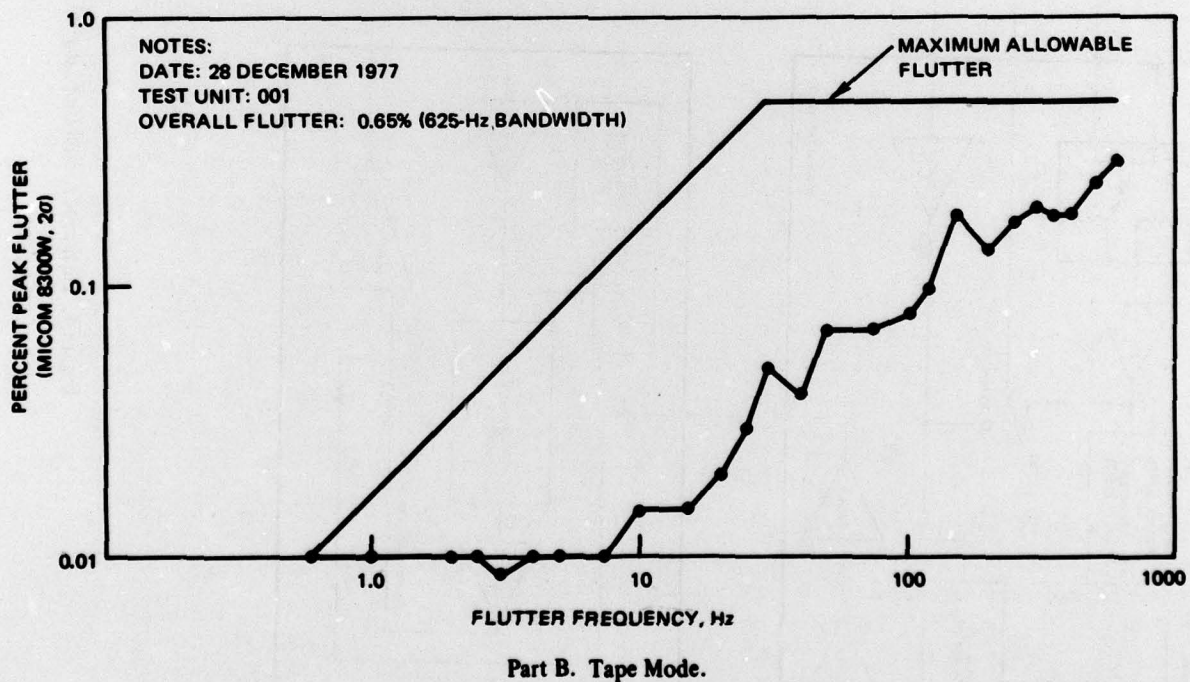
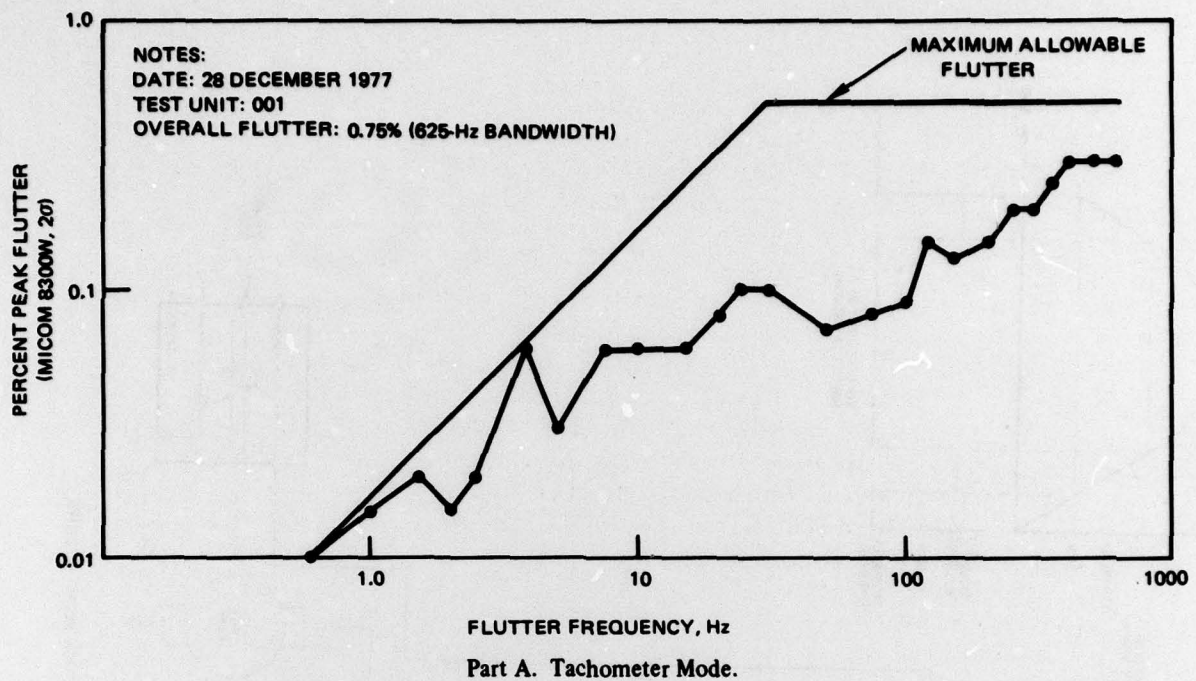


Figure 5. Flutter spectrum graph.

REPRODUCE SYSTEM

The reproduce system consists of two equalized reproduce amplifiers, a 12-position step attenuator, and a Nortronics two-track NAB-format reproduce head. The two amplifiers are installed on a single 2-1/2- × 3-1/2-in printed circuit board and are identical except for their final output stages. The output stage of the data-reproduce amplifier is gain controlled by the external 12-position step attenuator which provides 12 equal attenuator increments of 2 dB each. In the zero attenuation position, the system produces an output level of 5-V peak from a standard 185NW/M test tape. The output stage of the second reproduce amplifier is a comparator circuit which furnishes a TTL compatible square wave to the servo tape-speed control circuit.

The effective gap length of the reproduce head is 160 μ in. In general, the choice of reproduce gap length is a compromise between high-frequency response on the one hand and signal-to-noise ratio on the other. With a gap length of 160 μ in, the frequency response of the tape reproducer from 50 to 5000 Hz measures within ± 2 dB of the 500-Hz level and the RMS signal-plus-noise to RMS noise ratio measures 52 dB or better.

END-OF-TAPE (EOT) SENSOR

Even though there is no beginning or ending of tape in a continuous-loop tape cartridge, it is often required that a specific starting point of the data be established. This was accomplished in the present system by optically sensing the reflective foil used to splice the head-end of the tape-pack to its tail.

Two factors complicated the design of the EOT sensor: First the tape is enclosed in a cartridge with only the oxide surface available for sensor contact and second there was a requirement for uninterrupted playback through the splice region. Experiments with various splicing materials and techniques revealed that the use of 1/2-mil reflective splicing foil resulted in a reliable and nondisruptive splice. An optical-pair reflective sensor, including a gallium arsenide infrared light-emitting diode, is positioned over the tape cartridge so that it "looks" through the top of the cartridge and "sees" the backside of the tape as it emerges from the center of the tape-pack. Performance of this EOT system has proven very reliable. Once it is properly positioned a splice is never missed, even at a fast forward shuttle speed of 30 IPS.

POWER REGULATION

A specific design requirement of the tape reproducer was that there would be complete electrical isolation between the drive system, the signal processing system, shield grounds, and chassis ground. It was also specified that the only power to be furnished would be +28 VDC. These requirements were satisfied by first reducing the +28 VDC down to +15 VDC by means of a series regulator circuit. The +15 VDC furnish power for the servo drive circuits and provide an input to a hybrid, unregulated DC/DC converter which in turn provides isolated +15 VDC and -15 VDC for the signal circuits. All power conversion and regulation circuitry is contained in a 2- × 3- × 1/2-in module.

QUALIFICATION AND RELIABILITY TESTING

Earlier versions of the unit were subjected to extensive environmental and reliability testing. The demonstrated operating temperature range of the reproducer is +28 to +145°F. The qualified nonoperating (storage) temperature is -40 to +160°F. Several different vibration tests were imposed, ranging from a 6-h resonant search on each axis to a 20- to 2000-Hz random vibration at $0.001g^2/Hz$ in combination with temperatures of -20 and +145°F. The unit was also successfully subjected to shock, acceleration, humidity, and altitude environments in accordance with U.S. Navy approved procedures.

Recently, the Tape Reproducer was subjected to a reliability test per test plan VI (level A1) of MIL-STD-781 which successfully demonstrated an expected mean time between failures (MTBF) of 5000 h and a minimum acceptable MTBF of 1000 h.

FUNCTIONAL VARIATIONS

As in any magnetic-tape data-storage system, once the basic tape transport design has been implemented many functional variations are readily available depending only on the availability of record and reproduce heads and the space and power requirements for the support electronics. There is a great variety of tape heads on the market today, especially for 1/4-in tape. Available are one-, two-, three-, four-, five-, eight-, nine-, and ten-track record and reproduce versions of 1/4-in tape heads; two- and four-track read-after-write heads; single-head-stack, eight-track analog (staggered gaps) and eight-track in-line digital head stacks; etc.

The latest version of the Tape Loop Reproducer can be enclosed in a 4- x 5- x 8-in enclosure and support 50 in² of board space for data acquisition or record and reproduce signal-processing electronics. A sketch (figure 6) showing a recorder recently developed for the Navy by L'Garde with a microprocessor-controlled data acquisition system illustrates a typical method of packaging. This particular model furnishes 90 min of 15-kHz bandwidth analog or digital recording by sequencing through four tracks — one track at a time.

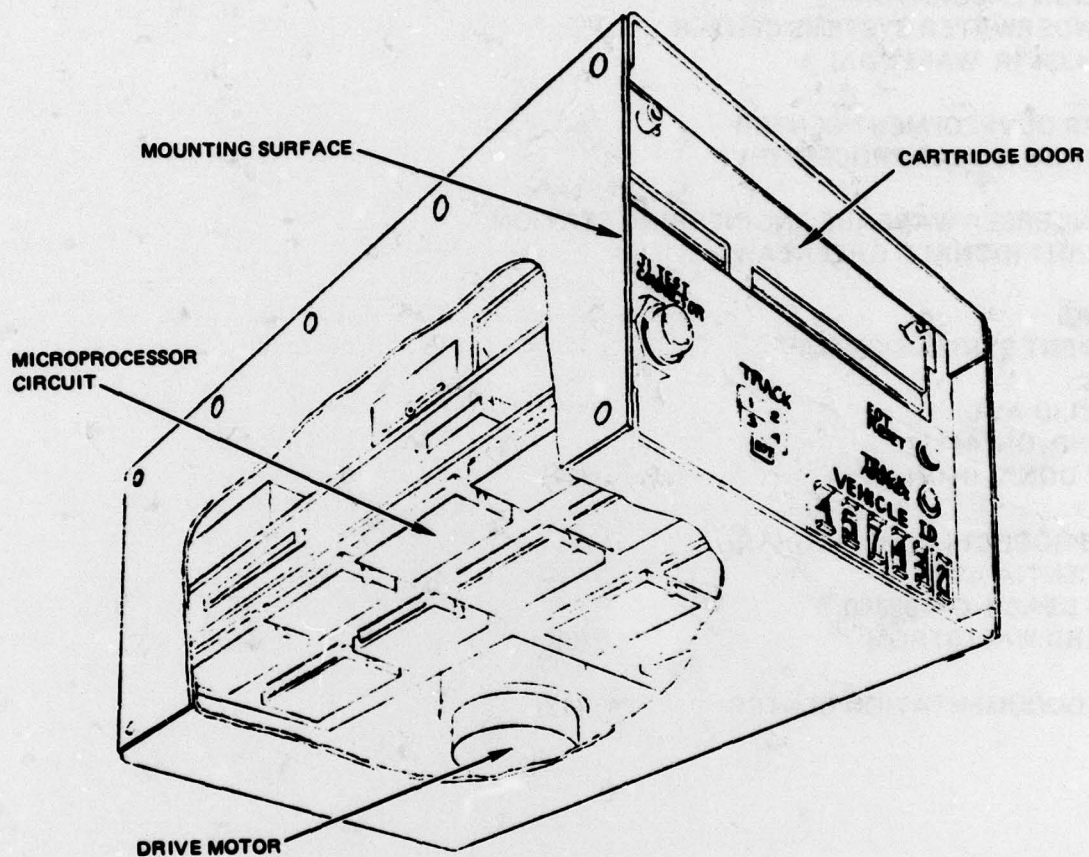


Figure 6. Recorder proposed by L'Garde Products Corporation.

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